Design and Evaluation the Bluetooth Mesh-Low Power Node Streaming in Wireless Sensor Networks

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***Abstract*—wireless sensor network (WSN) are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, and to cooperatively pass their data through the network to a main location. Thus, the Bluetooth one of the wireless signals that is used for communication sensors networks. However, this used many sensors devices in connected networks can also be considered problematic when considering power consumption. In addition to that, the vast majority of Low Power Nodes (LPN) that use Bluetooth low energy for communication run on small batteries, which dies after a period of time, and thus the issue with have very strict power requirements in WSN networks. Therefore, the design and development of network is carried out using Bluetooth Mesh-Low Power Node (M-LPN) flooding in WSN as wireless networking technology. However, Bluetooth M-LPNWSN architecture supports network topologies like mesh networks. As well as, develop analytical models for the Bluetooth M-LPNWSN average current consumption, and the theoretical lifetime of a battery-operated Bluetooth M-LPNWSN, the energy consumed per each user data bit delivered by the Bluetooth M-LPNWSN, and Analyze the behaviors of Friendship in the Bluetooth M-LPNWSN. The average time of spent by each type of node at different states is calculated for Bluetooth M-LPNWSN, it is found that a simple battery powered sensor with a capacity of 10 mAh, and send a data message every 1 millisecond, simulation time 60000, can achieve a lifetime at node 53 of up to 113.4586 days, while the approximate life is 365 days. The results conclude for Bluetooth M-LPNWSN that the low power nodes spend most of the time in sleep state unlike the Bluetooth M-LPN, resulting in energy conservation and increased lifetime, Bluetooth M-LPNWSN shows better performance compared with the conventional Bluetooth M-LPN and the lifetime of LPN improves by 56.164%.**

Keywords—Bluetooth, WSN, Bluetooth M-LPNWSN, Bluetooth M-LPN, LPN.

I. Introduction

The number of WSN in the any-area is increasing rapidly and is predicted to more than a thousand sensor nodes [1]. The telecommunication of WSN that used in each sensor network is a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors [2]. This includes a significant range of applications that will increase congestion on the license-free 2.4 GHz Industrial Scientific and Medical (ISM) band [3]. The communication protocols utilizing the ISM band need to coexist and preferably interoperate. However, this great increase in connected networks can also be considered problematic when considering power consumption. Moreover, the vast majority of LPN that use Bluetooth low energy for communication run on small batteries, which dies after a period of time, and thus the issue with have very strict power requirements [4, 5, 6]. Research has been conducted in Bluetooth mesh low energy networks to reduce energy consumption but the issue of high-energy consumption has still not been resolved. When the battery runs die in Bluetooth LPN networks, nodes are inoperable which makes the LPN networks useless. There are three modules in an LPN: sensing, processing, and communication. The largest consumer of power is the LPN communication module. The communication module transmits and receives data during the active state, and continuously scans the air interface for incoming messages during the idle state [3]. As well as, friend nodes and Time-to-Live (TTL) is a field in which all Bluetooth mesh low energy include and commonly used to improve the performance, increase lifetime for LPN and manage the caching of data and controls the maximum number of hops over which a message is relayed, but in fact and the issue for both features are still not good for reducing power consumption in Bluetooth low energy [3, 7]. In addition to that, there are three energy performance parameters that developed analytical models for reducing the power consumption and increase LPN lifetime in Bluetooth low energy such as the average current consumption, the theoretical lifetime of a battery-operated, and the energy consumed per each user data bit delivered by Bluetooth LPN, but it was not developed well to reduce energy consumption and make the LPN lifetime as long as required [4]. Therefore, problems and issues mentioned above, along with the impact that Bluetooth LPN networks can have on WSN development, will be addressed in this proposal during literature study and implementation and backed up to some extent with measurement results. This proposal focuses on investigating the possibility of making use of both the power consumption and the higher lifetime for the LPN by dynamically adjusting the configuration of the battery to allow building more energy-efficient sensor networks based on Bluetooth mesh low energy thus combining the energy efficiency of ultra-low-power radios with the interoperability of Bluetooth low energy with a long operational lifetime.

This paper comprehensively reviews the latest Bluetooth M-LPN flooding WSN networking. First, it introduces the WSN background and the design of the Bluetooth M-LPNWSN network. Then, it reviews features, stack, Friends nodes, LPN and describes a variety of approaches that take advantage of existing Bluetooth M-LPNWSN networks. it identifies critical aspects of Bluetooth M-LPNWSN interlocking network solutions and discusses their advantages. Finally, it highlights the current power consumption modeling with simulation for the Bluetooth M-LPNWSN system and comparing with traditional Bluetooth low energy.

II. Wireless Sensor Network (WSN)

WSN is a modern lesson of remote systems that are getting to be exceptionally well known with a colossal number of civilian and military applications. It may be a wireless network that contains disseminated free sensor devices that are implied to screen physical or natural conditions [8]. Hence, it is comprising of a set of connected minor sensor nodes, which communicate with each other and exchange data and information. These nodes get data on the environment such as temperature, pressure, humidity or toxin, and send this data to a base station. The last-mentioned sends the information to a wired network or enacts a caution or an activity, depending on the sort and greatness of information checked [9]. Normal applications incorporate climate and timberland checking, war zone reconnaissance, physical checking of natural conditions such as pressure, temperature, vibration, poisons, or following human and creature development in timberlands and borders. For nodes in a nearby zone network to communicate appropriately, standard get to protocols like IEEE 802.11 are accessible. Be that as it may, this and the other protocols cannot be specifically connected to WSNs. The major distinction is that, not at all like devices partaking in neighbourhood region systems, sensors are prepared with a really little source of energy (as a rule a battery), which channels out exceptionally quick [9]. Consequently, the requirement emerges to design unused protocols for MAC that are energy mindful.

III. Bluetooth M-LPNWSN System Design

Without any debate, Bluetooth Low Energy has ruled the WSN space. Applications like smart domestic, home-healthcare, and resource following enormous advantage from Bluetooth Low Energy capabilities. Be that as it may, Bluetooth Low Energy communication between devices has been restricted to either one-to-one or one-to-many. In expansion, the arrangement of Bluetooth Low Energy is challenging due to constrained range, particularly in situations like homes where a few devices may be covered up behind a few dividers relative to other devices. These factors have made it difficult to control the complete domestic from a single area. Many-to-many communication is required such that any node can get messages from numerous devices and send messages to different devices. For case, consider a gathering of four light bulbs that got to be controlled utilizing different portable phones. It too has to be able to get set messages from a dimmer and/or an inhabitancy sensor. This requires many-to-many communications. For Bluetooth Low Energy to be the foremost valuable in applications like smart home, smart buildings, and smart cities, engineers require many-to-many communications and a mechanism to expand the extend whereas permitting a few devices to function employing a little battery. Bluetooth Mesh addresses these concerns. Bluetooth Mesh is developing as a favoured home mechanization technology since nodes in a Bluetooth Mesh arrange can be gotten to specifically from a portable phone or tablet without the requirement for a gateway. Interoperability is the key to success for any smart home deployment as each smart home may utilize products from various vendors. Standard message formats for defined use cases (Models) enable rapid deployment and interoperability assurance with other Bluetooth M-LPNWSN products. This series of articles discusses key concepts required to understand Bluetooth M-LPNWSN. It will focus on Bluetooth M-LPNWSN capability, privacy and security features, and how to select a device for your smart home or agriculture application. This first proposed in the series discusses the key elements of a Bluetooth M-LPNWSN.

IV. Bluetooth M-LPNWSN Features

In Bluetooth mesh flooding, the network layer plays a significant part. All the network messages got and transmitted within the network layer utilize either the advertising conveyor or the GATT carrier. The relay and intermediary highlights within the organized layer offer assistance in empowering large-scale mesh systems. The transfer the highlight is utilized to relay/forward organize PDUs gotten by a node over the promoting conveyor. The intermediary includes is utilized to relay/forward network PDUs got by a node between GATT and advertising bearers. A Bluetooth M-LPNWSN consists of nodes with a few include sorts. Fig. 1 gives a high-level representation of a Bluetooth M-LPNWSN. As can be seen from the Fig., it has nodes with the taking after include sorts:

- Relay Node/Feature.
- Low Power Node (LPN)/Feature.
- Friend Node/Feature.
- End Node/Feature.
- GATT/Feature.

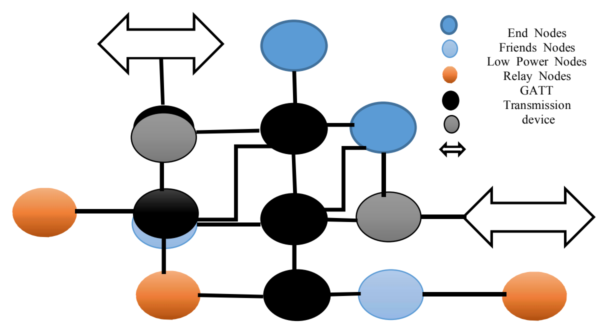

Fig. 1. Bluetooth M-LPNWSN system

The Relay highlight empowers a node to relay messages over the advertising carrier. Ordinarily, each powered node is likely to incorporate the Relay highlight as it has the control required to listen continuously for advertising packets and hand-off it to other nodes. An illustration of the Transfer highlight in utilizing maybe a smart light bulb or a wall-powered light switch within the home computerization application. On the other hand, nodes that operate on little batteries are improbable to have the Relay include because it requires Rx to be on continuously and for the device to listen to the publicized packets. Doing so would deplete the battery rapidly. The LPN feature is one of the foremost vital highlights of Bluetooth M-LPNWSN. Not at all like a node with the Relay include, a node with the LPN feature does not have to be compelled to tune in to publicized packets persistently. A node with an LPN feature spends most of its time in the device's low-power mode whereas its Friend node collects messages on its behalf. The LPN wakes up at characterized interims and pings its Friend nodes to check for any pending messages. After communication with the Friend Node, the LPN goes back to a low-power rest state. Usually a valuable highlight for applications that work on a battery. Applications such as sensor nodes within the home robotization, cost labels in a retail outlet, etc., can advantage from the LPN highlight. Be that as it may, the transmission time at the End node depends upon the application activity. Essentially, the transmission time at the LPN is affected by the arranged the esteem of the poll timeout. A node with the Friend highlight will tune in for any messages that are relayed within the network and planning for a related LPN. The Friend node will store these messages and provide it to the related LPN when the LPN wakes and queries the Friend node. Since the Friend Node has to store messages for one or more LPN, the Friend Node may require more memory than other node sorts. The sum of memory required is subordinate on the sum of data/commands required to be put away on the Friend node that will be communicated to the LPN amid a polling operation. The Bluetooth core specification includes a low energy version for low-rate wireless sensor network, referred to as Bluetooth M-LPN or Bluetooth Smart such as NRF52840, 2020. The Bluetooth M-LPN stack consists of the: GATT, ATT, Security Manager Protocol (SMP), L2CAP, LL and PHY as shows in Fig. 2 [10]. The Bluetooth M-LPN was added to the standard for low energy devices generating small amounts of data, such as the notification alerts used in applications like smart home, smart agriculture, health-care, fitness, and WSN. As well as, The Bluetooth M-LPN profile such as nrf52840 dongle defines the fundamental requirements to implement mesh networking solutions for Bluetooth M-LPN. The mesh stack is located on top of the Bluetooth M-LPN core specification and consists of the [5]:

- Model Layer characterizes the models, messages, and states required for client scenarios. For example, to alter the state of light to on or off, a Generic on-off set message from the non-specific on-off demonstration is utilized. This proposed supports as it were two models, generic on-off and light gentility with set and status messages.
- Foundation Model Layer characterizes the models, messages, and states required to arrange and oversee the work network. This layer is utilized to arrange components, distribute, and membership addresses. This proposed expect that the node is designed with all addresses.
- Access Layer characterizes the interface to the upper transport layer and the arrangement of the application information. It too controls the encryption and unscrambling of the application information within the upper transport layer. This proposed supports retransmissions and affirmations at this layer. The functionality of the upper transport layer includes encryption, decryption, and authentication of the application data and is designed to provide confidentiality of access messages. This layer is also responsible for the generation of transport control messages (friendship and heartbeat) internally and transmits those messages to a peer upper transport layer. These messages are encrypted and authenticated at the network layer. In this proposed encryption, decryption, authentication, and heartbeat messages are not supported. The functionality of the lower transport layer includes segmentation and reassembly of upper transport layer messages into multiple lower transport layer messages to deliver large upper transport layer messages to other nodes. This layer also defines the friend queue used by the Friend node to store the lower transport layer messages for a low power node. In this proposed, segmentation and reassembly are not supported and both the upper and the lower transport layers are implemented as a single transport layer object.
- Network Layer defines the encryption, decryption, and authentication of the lower transport layer messages. It transmits the lower transport layer messages over the bearer layer and relays the mesh messages when the Relay feature is enabled. It also defines the message cache containing all the recently seen network messages. If the received message is found to be in the cache, then it is discarded. The message cache is used by the relay nodes (nodes in which the 'Relay' feature is enabled). In this proposed encryption, decryption and authentication are not supported.
- Bearer Layer is an interface between the Bluetooth M-LPN stack and the Bluetooth Low Energy core specification. It is also responsible for creating a mesh network by provisioning the mesh nodes. This proposed assumes all the nodes are already provisioned into a mesh network. The two types of bearers supported by the B Bluetooth M-LPN are advertising bearer and GATT bearer. This proposed considers only the advertising bearer.
- Generic Access Profile defines advertising data (AD) types for carrying mesh messages over the advertising bearer. This Bluetooth M-LPN supports the Mesh message AD type and it is used for exchanging network layer messages between mesh nodes.
- Link Layer defines Broadcaster and Observer roles for message exchange between the nodes within the Bluetooth M-LPN network. In a Broadcaster role, a node always advertises whereas in an observer role the node always scans for the advertisers. Each node in the mesh network switches between these two roles to serve as a Bluetooth M-LPN. Fig. 3.2 illustrate mesh stack is located on top of the Bluetooth M-LPN core specification.

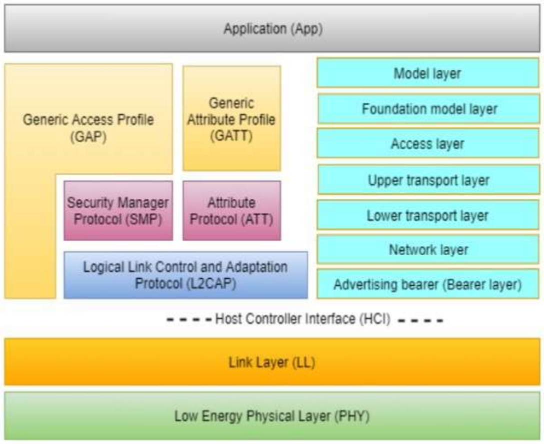

Fig. 2. Bluetooth M-LPNWSN stack over the advertising bearer.

V. Bluetooth M-LPN Managed Flooding WSN

The Bluetooth mesh profile indicates the methods to optimize the flooding operation for a productive network. Usually called managed flooding. Therefore, the major strategies utilized in overseen flooding are [5]:

- Message Cache: All nodes must execute a network message cache. The message cache contains all the as of late seen arranges messages. In case they gotten message is found to be within the cache, at that point it gets discarded.
- TTL controls: the number of bounces a message is transferred in an organization. Choosing an ideal TTL esteem moderates' power over the organization. On the off chance that the TTL esteem at a node is more prominent than or break even with to 2, it demonstrates that the message may have been handed-off and can be relayed. TTL esteem less than 2, shows the message may have been transferred but will not be relayed.
- Heartbeats: Pulse messages are sent by the nodes intermittently. It is utilized as a sign to the accepting nodes, that the sending node is lively. At the accepting node the ideal TTL esteem for distributing a message to the sender is determined from the heartbeat message.

VI. Low Power Support in Bluetooth M-LPNWSN

Since Bluetooth M-LPNWSN run on limited energy sources (e.g., small batteries), it remain by default in sleep mode in order to save energy Bluetooth M-LPNWSN can transmit messages at any time, since it is assumed that at least one of their next hop devices will be always ready to receive and forward such messages. However, in order to allow Bluetooth M-LPNWSN be able to also receive messages, Bluetooth Mesh Upper transport layer defines the concept of a friendship, which is a special relationship between a Bluetooth M-LPNWSN and a one-hop neighbour which it refers to as Bluetooth Mesh-Friend Node. The latter, which is selected by the former among its one-hop neighbours, stores messages intended for the Bluetooth M-LPNWSN while this node is in sleep state. The Bluetooth M-LPNWSN asynchronous-sly polls the Bluetooth Mesh-Friend Node for possible incoming messages by sending a request message to the latter. After sending the request, the Bluetooth M-LPNWSN returns to sleep mode. After Receive Delay ms, which allow the Bluetooth Mesh-Friend Node to prepare a response, the Bluetooth M-LPNWSN starts listening for up to Receive Window ms. Upon receipt of a request, the Bluetooth Mesh-Friend Node can send a stored message to the Bluetooth M-LPNWSN, if any. After receiving the last stored message, or after the end of the receive interval, the Bluetooth M-LPNWSN enters sleep mode again. The maximum time between two consecutive requests is defined by the poll Timeout parameter. Fig. 3 depicts a diagram that represents the described polling process.

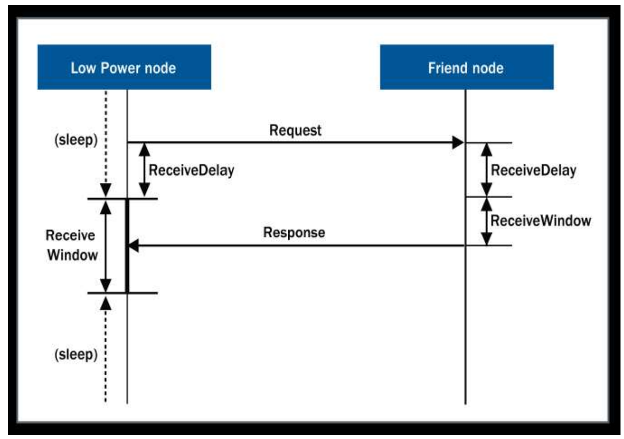

Fig. 3. Illustration of a Bluetooth M-LPN polling a Bluetooth M-FN, and the related Bluetooth Mesh parameters involved.

Ordinarily, a Bluetooth M-LPNWSN running as a sensor gadget will intermittently poll the Bluetooth Mesh-Friend Node and filter the channel after each ask for getting Window ms, in expansion to sending information messages containing sensor readings as appears in Fig. 4. Note that, since advertisements are for the most part utilized to carry Bluetooth Work messages, one request or one information message transmission is ordinarily performed by sending 3 advertisements.

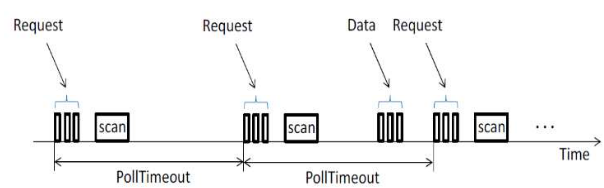

Fig. 4. Polling and data message transmission operations carried out by a Bluetooth M-LPNWSN.

VII. Friendship in Bluetooth M-LPNWSN System

WSN is known to be an exceedingly resource-constrained lesson of networks where energy consumption is one of the elemental concerns. Most of the sensors are battery-powered devices. In WSNs, sensor nodes are conveyed on a huge scale and hence it is unreasonable to supplant the batteries of sensor nodes. In this manner, each sensor node must utilize power effectively to outlive for a long time. The Bluetooth M-LPNWSN characterizes the friendship usefulness for the energy-constrained gadgets. The transport layer (upper and lower) within the Bluetooth M-LPNWSN is primarily mindful of the Friendship usefulness. It characterizes two sorts of nodes. [5]. A low power node incorporates a constrained control source and works at diminished recipient obligation cycles. This node switches to on state as it were to get information packets. A friend node empowers the friend to highlight and stores the messages ordained for low power nodes. This node transmits the messages as it was when the low power nodes unequivocally request. This proposed bolsters friendship between one friend and one low power node. Companionship is built up between friends and low power nodes. The low power node starts the companionship as before long because it is provisioned into the Bluetooth M-LPNWSN network. This proposed to accept that fellowship is as of now set up between companions and low power nodes. After the friendship is set up, the friend node stores the messages on behalf of a low power node within the friend line. A polling instrument is utilized for optimizing energy consumption at the low power nodes. The Bluetooth work message trade between the low power node. Get delay parameter indicates the time between low power node sending a request and tuning in for a reaction from the friend node. The low power node is in a rest state for the total length of the get delay. The collector window parameter indicates the time for which a low power node tunes in for a reaction from the friend node. low power node is within the checking state for the total term of the get window. The poll timeout parameter indicates the most extreme time between two successive demands from a low power node. Inside the poll timeout, in case the friend node or the low power node comes up short to get an ask or reaction from the other node, friendship is ended. Occasionally, low power nodes poll friend nodes for any information messages put away within the friend line. After polling the Friend node, low power nodes enter the sleep state for the length of getting delay. The Friend node employments the get delay getting ready the reaction for the low power node. After the get delay, the friend node reacts to the low power node sometime recently the whole of getting delay and get the window. Bluetooth M-LPNWSN is designed to empower device to have exceptionally low power consumption. A few chipmakers counting Cambridge Silicon Radio, Discourse Semiconductor, Nordic Semiconductor, STMicroelectronics, Cypress Semiconductor, Silicon Labs, and Texas Rebellious had presented Bluetooth Low Energy optimized chipsets by 2014. Devices with fringe and central parts have distinctive power necessities. A think about by signal software company Walkway labs detailed that peripherals such as vicinity guides as a rule work for 1–2 a long time fuelled by a 1,000mAh coin cell battery. This can be conceivable since of the power effectiveness of Bluetooth Low Energy protocol, which as it were transmits little. packets as compared to Bluetooth Classic which is also suitable for audio and high bandwidth data.

VIII. Modeling and Simulation the power Consumption of Bluetooth M-LPN WSN

The design of the Bluetooth M-LPNWSN network, consisting of a fifty-five nodes mesh network, and some of these nodes are conFig.d as friends, low power, relays, and end nodes as shows in Fig. 5. The source and destination node pairs, power source, and their corresponding TTL values are specified and the paths between source and destination nodes are identified. Moreover, the friend node supports the LPN to stay live for a long time. The simulations show that there is a chance of having a path between the selected source and destination nodes, even if some of the intermediate relay and end nodes fail in the network. Within the final two sections, it modelled and evaluated the energy consumption execution parameters of a Bluetooth M-LPNWSN. Fig. 5 also illustration friend node, relay nod, listen node, and sleep node for Bluetooth M-LPNWSN. While the simulation is running, each node calculates the time spent in various states (transmission, listen, idle and sleep) of the node. This helps in calculating the lifetime of a node within the network. it simulated this, Bluetooth M-LPNWSN with 55 nodes randomly distributed in a 160m - 200m field. Moreover, it observes that Bluetooth M-LPNWSN takes some advantage than Bluetooth M-LPN in terms of node life time and transmission. It is due to the fusion between Bluetooth M-LNP and the balanced way in term of cluster head election introduced by the Bluetooth M-LPNWSN. One of the fundamental features of a project is its unitability for the low power and energy-constrained nodes. This proposed models the energy profiling of low power, battery operated Bluetooth M-LPNWSN that implement an energy saving feature called friendship. Energy is computed based on the time profiled at various states (transmission, listen, sleep and idle) of each node in WSN. The derived results show that the low power nodes always consume less energy by spending more time in sleep state, thus resulting in energy conservation and increased lifetime.

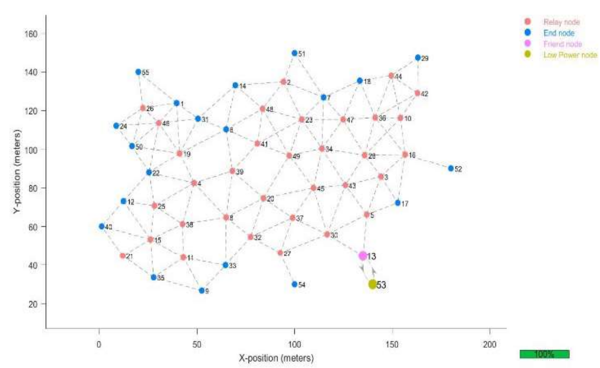

Fig. 5. Bluetooth M-LPNWSN stack over the advertising bearer.

The performance of proposed prove more the Bluetooth M-LPNWSN for transmission, listen, and idle in friend nodes is always larger than the relay nodes, low power nodes, and end nodes. The lifetime of a low power node depends on the time for which the node is in listen state. Most of the time, a low power node is in listen or sleep, idle state for a given poll timeout. The time for which the node is in listen state is determined by the receive window for every poll request made by the low power node. The low power node spends the remaining time in sleep, idle and transmission state. However, the time spent in listen state for low power node is nil. The average time of spent by each type of node at different states is calculated for Bluetooth M-LPNWSN. The results conclude for Bluetooth M-LPNWSN that the low power nodes spend most of the time in sleep and listen state unlike the Bluetooth

M-LPN, resulting in energy conservation and increased lifetime as shows in Fig. 6.

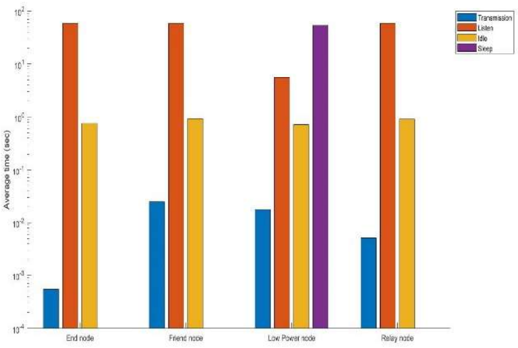

Fig. 6. Average time statistics of deferent Bluetooth M-LPNWSN.

Based on the profiles of the advertisement transmissions and the checking interim, another calculates the Bluetooth M-LPNWSN normal current consumption. It to begin with the objective is deciding the Bluetooth M-LPNWSN normal current consumption, indicated Current Average. As presented in Section 3.2 (Bluetooth M-LPN Stack) Bluetooth M-LPNWSN remains in rest mode by default, and each Poll Timeout sends an ask to its Bluetooth Mesh-Friend Node. In expansion, the Bluetooth M-LPNWSN transmits a data message once each. (T_{Data} $=T_{Ifs}+T_{ACK}+T_{Ifs}-T_{min}$). Since the last-mentioned performs a request-scan cycle each Poll Timeout, and it transmits a sensor perusing each T_{Data}, Current Average can be gotten as appeared following [4].

$$Current_{Average} = \frac{1}{polltimeout}\left(\sum_{i=0}^{13} T_i I_i + \frac{polltimeout}{T_{Data}}\sum_{i=1}^{9} T_i I_i\right) \quad (1)$$

It cannot settle limits are expressed by the Core Determination for Bluetooth Low Energy in respects to the number of transmissions inside a single Association Occasion, in spite of the fact that the last frame must be gotten at slightest Interframe space (T_{Ifs}) sometime recently the beginning of the taking after connection event. A single transmission is composed of one Information frame, one acknowledgment (ACK) frame, and the correspondent [11].

$$T_{min} = T_{\text{Data}} + T_{\text{Ifs}} + T_{\text{ACK}} + T_{\text{Ifs}} \quad (2)$$

where T_{min} is round trip time, T_{Data} and TACK are the time duration of a Data and an ACK frame, respectively. As can be seen, Current Average can be determined by using Equations (1) and (2).

$$Current_{Average} = \frac{1}{polltimeout}\left(\sum_{i=0}^{13} T_i I_i + \frac{polltimeout}{T_{\text{Ifs}} + T_{\text{ACK}} + T_{\text{Ifs}} - T_{min}}\sum_{i=1}^{9} T_i I_i\right) \quad (3)$$

The following decide the normal term of the rest interim inside a poll timeout interim, T_{sleep}. Let Tact be the normal add up to a term of all states wherein the device isn't in sleep mode. Then, T_{sleep} can be calculated as:

$$T_{Sleep} = \text{polltimeout} + T_{\text{act}} \quad (4)$$

where Tact can be gotten as appeared within the following equation:

$$T_{\text{act}} = \sum_{i=0}^{13} T_i + \frac{polltimeout}{T_{\text{Ifs}} + T_{\text{ACK}} + T_{\text{Ifs}} - T_{min}}\sum_{i=1}^{9} T_i \quad (5)$$

As can be seen, Current Average can be determined by using Equations (1) and (5). Based on this performance parameter, it is possible to obtain the theoretical lifetime of a Bluetooth M-LPNWSN, denoted Lifetime, assuming a battery capacity of Capacity battery (expressed in mAh), and a battery self-discharge current, $I_{\text{self-discharge}}$, as shown next:

$$T_{\text{lifetime}} = \frac{\text{Capacity}_{\text{battery}}}{Current_{\text{Average}} + I_{\text{self-discharge}}} \quad (6)$$

Note that the previous equation aims at capturing an important aspect of a realistic battery behaviour, which is the degradation of its characteristics over time. it assumes that $I_{\text{self-discharge}}$ is a constant value as a function of time. Finally, it also models the energy consumed by the Bluetooth M-LPNWSN per user data bit delivered to a neighbour, $E_{Cdelivery}$. Let V indicate the battery voltage of the Bluetooth M-LPNWSN. Let $E[I_{delivery}]$ denote the expected number of user data bits delivered per ($T_{Ifs}+T_{ACK}+T_{Ifs}-T_{min}$). It obtains $E_{Cdelivery}$ as shown next:

$$T_{\text{lifetime}} = \frac{Current_{\text{Average}}\, V\,(T_{\text{Ifs}} + T_{\text{ACK}} + T_{\text{Ifs}} - T_{min})}{E_{[I_{\text{delivery}}]}} \quad (7)$$

Then, assuming that frame losses are uncorrelated, the expected amount of data delivered by the device per transaction is determined as:

$$E_{[I_{\text{delivery}}]} = I_{\text{Payload}}\ (1 - FLR^3) \quad (8)$$

Where $EI_{delivery}$ depends on the frame loss rate (FLR), and on the payload size, denoted $I_{Payload}$. The data message sent by the Bluetooth M-LPNWSN will be correctly delivered to a next hop if at least one of the corresponding three individual advertisement transmissions that carry the data message is successfully received. Bluetooth M-LPNWSN enables end-to-end communication in large-scale device networks to support applications like smart lighting, industrial automation, sensor networking, asset tracking, and many other WSN solutions. This result shows the plot of lifetime of low power node at node 53 as a function of poll timeout for receive window values 1 milliseconds, 10 milliseconds and 20 milliseconds. System parameter that used for Bluetooth M-LPNWSN as illustrates in table 1.

TABLE 1. Parameters that used in simulation proposed.

Parameters	Value
T_{Ifs}	0.5 ms
ACK	40 bytes
BLE radio throughput	2 Mbps
Message size	41 bytes
Transmission power	0 dBm
size	160 m x 200
Total Nodes	55
Battery Capacity	10 mAh

The results in the derived plot conclude that the lifetime of low power node is directly proportional to the poll timeout compared to the Bluetooth M-LPN as shows in Fig. 7. Fig. 8 illustrates a Bluetooth M-LPNWSN network with the Bluetooth M-LPN for node lifetime versus receive time out. It found that Bluetooth M-LPNWSN network better than the Bluetooth M-LPN, where the node life time stay long. Fig. 9 determining the energy consumed per delivered bit $EC_{delivery}$, for a battery-operated Bluetooth M-LPNWSN by using equations (7) and (8). The results obtained as a function of poll timeout, for different receive window and (T_{Ifs}+T_{ACK}+T_{Ifs}-T_{min}) setting, and different FLR values.

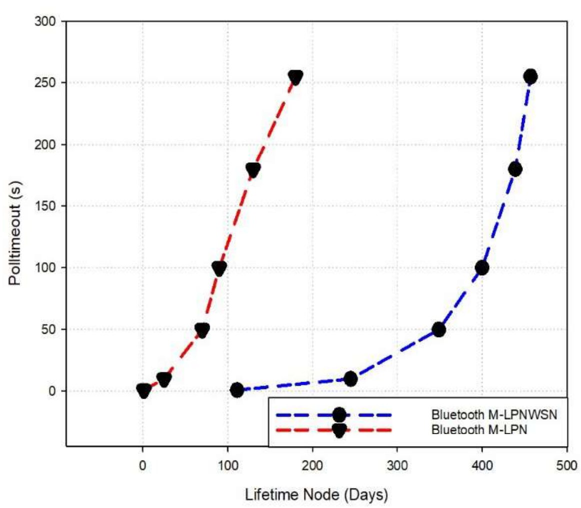

Fig. 7. Life time node versus poll time out for both (A) Bluetooth M-LPNWSN (B) Bluetooth M-LPN system

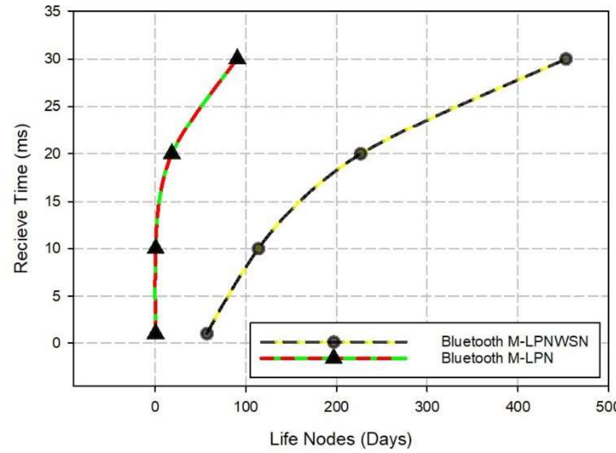

Fig. 8. Life node versus receive time for both (A) Bluetooth M-LPNWSN (B) Bluetooth M-LPN system

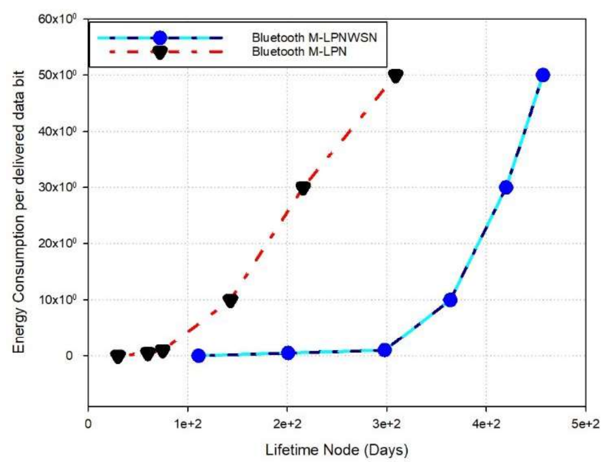

Fig. 9. Life time node versus energy consumption for both (A) Bluetooth M-LPNWSN (B) Bluetooth M-LPN system

Fig. 10 depicts the lifetime node of the Bluetooth M-LPNWSN, in receive window, for the same Poll time out settings considered. Fig. 11 shows the theoretical Bluetooth M-LPNWSN lifetime is inversely proportional to the average current consumption. Bluetooth M-LPNWSN lifetime grows with Poll time out, with an asymptotic lifetime of 365 days that is limited by the sleep state current consumption. For low Poll time out values, the Receive window setting becomes relevant, since active states have relatively significant duration and current consumption compared to sleep intervals. Bluetooth M-LPNWSN current consumption decreases with poll time out, and increases with receive window. For high Poll time out values, using different receive window settings leads to negligible performance differences. Remarkably, the data message transmission rate is irrelevant in terms of current consumption, except for very high sending rates in the order of 1 Hz or greater. The energy consumed by the Bluetooth M-LPNWSN by each delivered bit increases with (T_{Ifs}+T_{ACK}+T_{Ifs}-T_{min}), as in fact the energy consumed during sleep intervals is significant. Message losses increase the energy cost of data delivery.

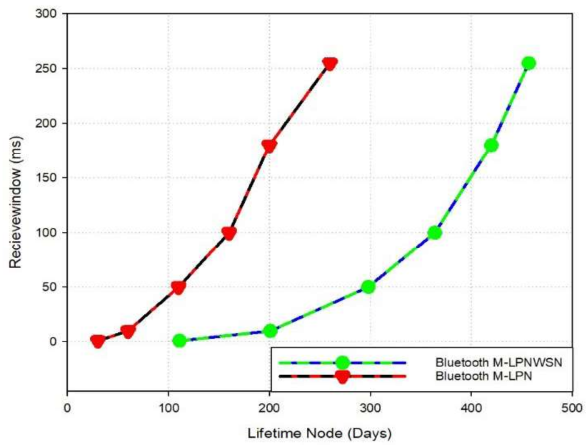

Fig. 10. Life time node versus receive window for both (A) Bluetooth M-LPNWSN (B) Bluetooth M-LPN system

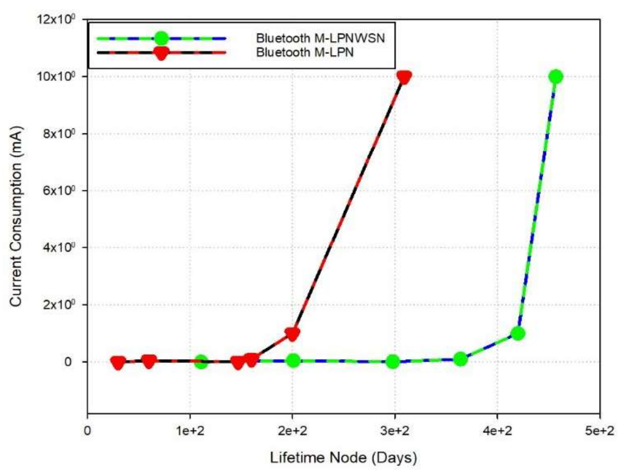

Fig. 11. Life node versus current consumption for both (A) Bluetooth M-LPNWSN (B) Bluetooth M-LPN system

CONCLUSSION

This paper presents Bluetooth M-LPNWSN protocol, an opportunistic routing based wireless mesh network protocol for Bluetooth. The goals of this study are creating and conFig. the proposed of Bluetooth M-LPNWSN protocol and visualize message flooding. Thus, the mesh network can be used to connect separate sensor networks, to connect sensor nodes with a monitoring platform, or as a scalable backbone for sensor to sensor communication. However, analyse the behaviour of friendship in the proposed and profile the energy consumed by each node in the proposed. In addition to that, the proposed enables many to many device communications and is optimized for creating large-scale device networks. It is ideally suited for building automation, sensor network, asset tracking, and other IoT solutions that require tens, hundreds or thousands of devices to communicate with one another. Therefore, Bluetooth M-LPNWSN protocol technology allows Bluetooth devices to be linked together to form a large network. By extending Bluetooth 5 with M-LPNWSN protocol many devices can now be connected in a network and thus communicate with each over long distance in an energy-efficient and secure manner. The Bluetooth M-LPNWSN protocol is simulated and evaluated by using MATLAB version R2020a.

ACKNOWLEDGMENT

The article and the presentation were made with the support of "Supervisor Dr. Amran Ahmad and School of Computing, College of Arts and Sciences, Universiti Utara Malaysia (UUM)".

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